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Performance and Age of the Fastest Female and Male 100-km Ultramarathoners Worldwide From 1960 to 2012

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Abstract

Cejka, N, Knechtle, B, Rüst, CA, Rosemann, T, and Lepers, R. Performance and age of the fastest female and male 100-km ultramarathoners worldwide from 1960 to 2012. *J Strength Cond Res* 29(5): 1180–1190, 2015—The purpose of this cross-sectional study was to investigate the change in 100-km running performance and in the age of peak performance for 100-km ultramarathoners. Age and running speed of the annual fastest women and men in all 100-km ultramarathons held worldwide between 1960 and 2012 were analyzed in 148,017 finishes with 18,998 women and 129,019 men using single, multivariate, and nonlinear regressions. Running speed of the annual fastest men increased from 8.67 to 15.65 $km \cdot h^{-1}$ and from 8.06 to 13.22 $km \cdot h^{-1}$ for the annual fastest women. For the annual 10 fastest men, running speed increased from 10.23 ± 1.22 to 15.05 ± 0.29 $km \cdot h^{-1}$ ($p < 0.0001$) and for the annual 10 fastest women from 7.18 ± 1.54 to 13.03 ± 0.18 $km \cdot h^{-1}$ ($p < 0.0001$). The sex difference decreased from 56.1 to 16.3% for the annual fastest finishers ($p < 0.0001$) and from 46.7 ± 8.7% to 14.0 ± 1.2% for the annual 10 fastest finishers ($p < 0.0001$). The age of the annual fastest men increased from 29 to 40 years ($p = 0.025$). For the annual fastest women, the age remained unchanged at 35.0 ± 9.7 years ($p = 0.469$). For the annual 10 fastest women and men, the age remained unchanged at 34.9 ± 3.2 ($p = 0.902$) and 34.5 ± 2.5 years ($p = 0.064$), respectively. To summarize, 100-km ultramarathoners became faster, the sex difference in performance decreased but the age of the fastest finishers remained unchanged at ~35 years. For athletes and coaches to plan a career as 100-km ultramarathoner, the age of the fastest female and male 100-km ultramarathoners remained unchanged at ~35 years between 1960 and 2012 although the runners improved their performance over time.

Key Words running, master athletes, sex difference, ultra-endurance performance

Introduction

In the last years, there has been an increased interest in analyzing factors affecting performance in endurance and ultra-endurance running such as physiological characteristics (35,40,46,49), psychological aspects (17,20,34), anthropometric (28,29) and training characteristics (29,32), previous experience (28,30), and the sex difference in performance (1,11,26).

Further, several studies focused on analyzing the influence of aging on running performance for different running distances (14,36,52). Age-related changes in endurance running performance have been reported to depend on sex (31), leisure or occupational physical activity (40), lifestyle (37), and disease (40).

Ultramarathon running races became increasingly popular in the past 20 years (21,23,24). Over the past decades, the participation of master athletes–defined as athletes older than 35 years (43)–increased in ultramarathon races (23,24,31). In a 100-km ultramarathon such as the "100-km Lauf Biel" in Switzerland, the age group with the largest participation was the age group 40–49 years for both women and men (31). It has been shown that these middle-aged ultramarathoners were mainly married men, well educated, and maintained a healthy lifestyle (22).

The population in both developed and developing countries is aging, consequently the number of master athletes is expected to proceed with the increase as well (41,52). The demography of age structure has changed in recent years and is predicted to continue over the next 50 years. The number of older adults is on the rise because of the considerable increase in longevity and decreasing fertility worldwide (41).

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Table 1. Comparison of linear and nonlinear regression analyses of running speed, sex difference, and performance density across years to determine which model is the best.*

	Kind of regression	Sum of squares	DOF	AIC	Best regression AIC-test	Best regression F-test	Delta	Probability	Likelihood (%)
Running speed annual top									
Women	Polynomial	14.8	37	−33.57	Polynomial	Linear	38.62	4.10×10^{-09}	100
	Linear	47.05	42	5.04					
Men	Polynomial	29.45	44	−16.02	Polynomial	Polynomial	45.56	1.27×10^{-09}	100
	Linear	85.81	47	29.54					
Running speed annual top 10									
Women	Polynomial	9.57	32	−41.0	Polynomial	Polynomial	34.71	2.89×10^{-09}	100
	Linear	27.52	33	−6.29					
Men	Polynomial	3.08	39	−107.90	Polynomial	Polynomial	88.13	7.28×10^{-20}	100
	Linear	26.76	42	−19.77					
Sex difference									
Annual fastest	Polynomial	728.25	41	136.02	Polynomial	Linear	42.52	5.82×10^{-09}	100
	Linear	2,132.06	44	178.55					
Annual 10 fastest	Polynomial	255.72	30	82.58	Polynomial	Linear	28.31	2.89×10^{-09}	99.99
	Linear	738.96	34	110.9					
Performance density									
Women	Polynomial	515.8	31	100.9	Polynomial	Polynomial	37.73	6.40×10^{-09}	100
	Linear	1,731.5	33	138.6					
Men	Polynomial	364.0	30	83.6	Polynomial	Polynomial	2.94	0.18	81.31
	Linear	426.2	31	86.5					

*AIC = Akaike's information criteria.

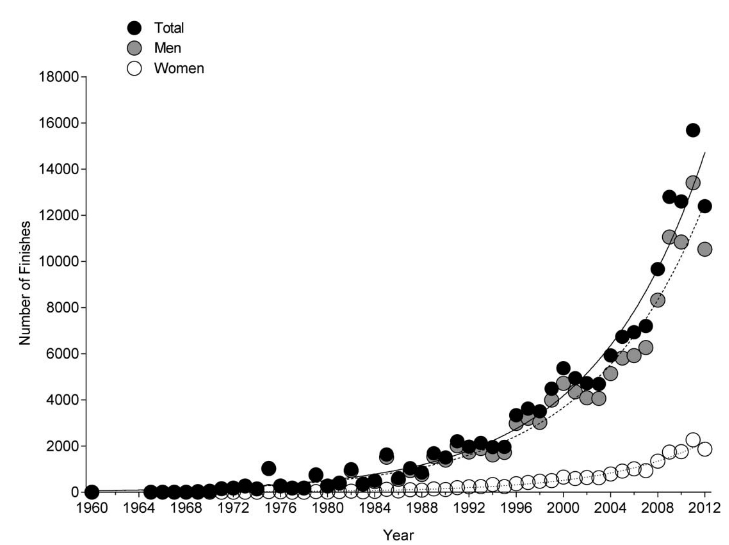

Figure 1. Number of finishes.

Over the past few years, it has been observed that the age of peak running performance in ultramarathoners increased for both women and men (11,21,24,31). In 100-miles ultramarathoners in the "Western States 100-Miles Endurance Run," the ages of the fastest runners have gradually risen to the extent that these runners were older than the ages at which the fastest marathons were run (24). In the "100-km Lauf Biel" in Switzerland, the fastest 10 women and men peaked at a similar age in ultramarathon running performance with 39.4 ± 2.3 years for men and 40.4 ± 1.9 years for women, respectively (31). The top performance in a 100-km ultramarathon was

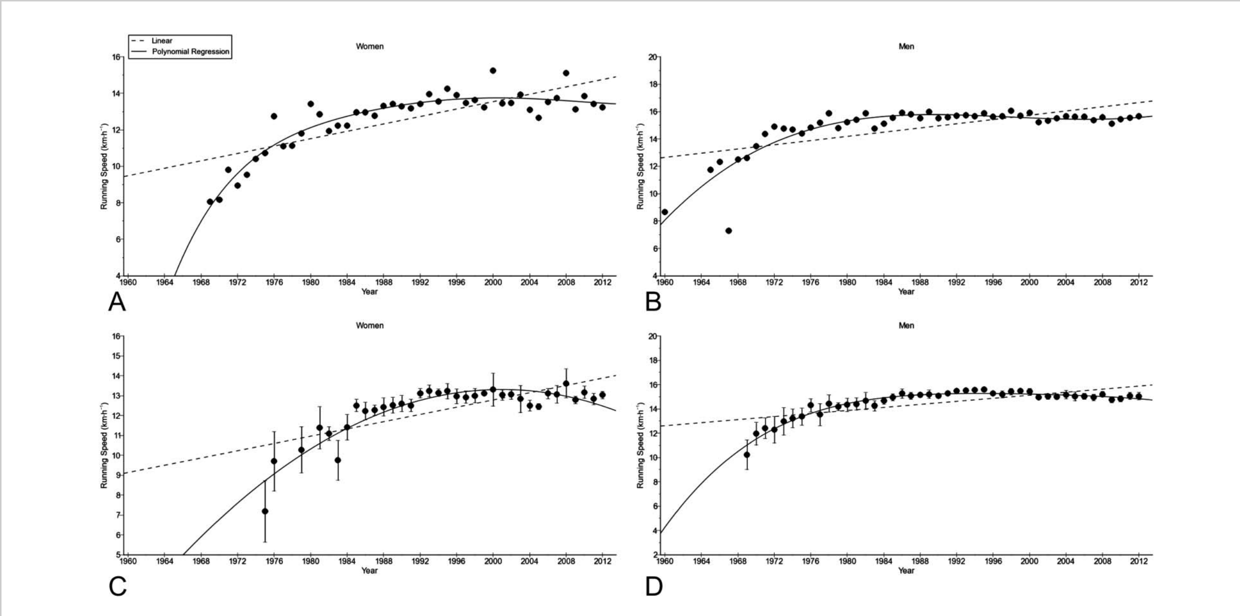

Figure 2. Running speed of the annual fastest women (panel A) and men (panel B) and the annual 10 fastest women (panel C) and men (panel D).

attained at a higher age compared with a 42-km marathon (26,31). Thus, a large number of training years and extensive previous experience in endurance running is needed for a successful finish in an ultramarathon (24,29,31). Similar findings for the increase in the age of peak ultra-endurance performance have been reported for Ironman triathletes. In the "Ironman Hawaii," the age of the annual top 10 women and men increased between 1983 and 2012, and the athletes were able to improve their performance (18). However, when worldwide trends in ultramarathon running were investigated, the age of peak ultramarathon performance remained unchanged. In 100-miles ultramarathoners, the mean ages of the annual 10 fastest runners were 39.2 ± 6.2 years for women and 37.2 ± 6.1 years for men between 1998 and 2011 although both women and men improved running performance (45).

Apart from age, sex has been distinguished as an important influencing factor of running performance (5,26,27). For example, men have larger hearts, a higher cardiac output, and a greater muscular strength compared with women (5,39). Sex differences in physiological and anthropometric characteristics may explain the better performance in men compared with women for endurance running (5,27,39). Several studies investigated the sex differences in running performance and suggested that the sex gap would narrow with increasing length of the race distance (1,51). Speechly et al. (51) reported that women who were matched with men on their performance at 42.2 km were able to outrun men in a 90-km race. In contrast, Sparling et al. (50) showed that the sex difference in distance running has not evolved in recent years.

Table 2. Multilevel regression analyses for change in running speed across years for the annual fastest and annual 10 fastest women and men (model 1) with correction for multiple finishes (model 2) and with correction for multiple finishes and age of athletes with multiple finishes (model 3).

	Model	β	*SE* (β)	Stand. β	*T*	*p*
Annual fastest men	1	0.077	0.014	0.640	5.705	<0.0001
	2	0.077	0.014	0.640	5.705	<0.0001
	3	0.084	0.014	0.696	5.953	<0.0001
Annual fastest women	1	0.101	0.013	0.780	8.068	<0.0001
	2	0.101	0.013	0.780	8.068	<0.0001
	3	0.095	0.009	0.728	10.850	<0.0001
Annual 10 fastest men	1	0.063	0.003	0.656	18.195	<0.0001
	2	0.063	0.003	0.656	18.195	<0.0001
	3	0.063	0.003	0.663	18.365	<0.0001
Annual 10 fastest women	1	0.091	0.005	0.670	16.845	<0.0001
	2	0.091	0.005	0.670	16.845	<0.0001
	3	0.091	0.005	0.672	17.598	<0.0001

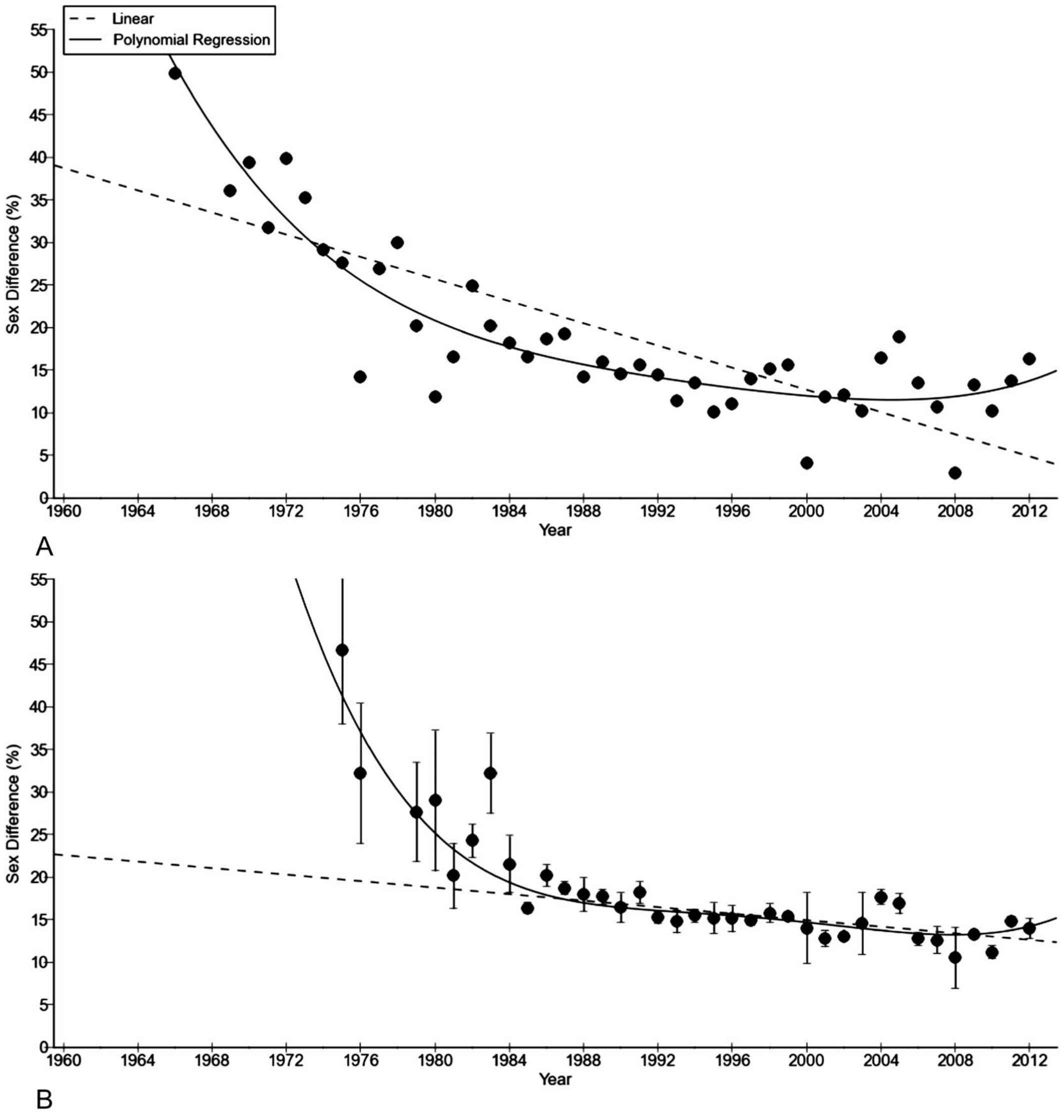

Figure 3. Sex difference in running speed for the annual fastest women and men (panel A) and the annual 10 fastest women and men (panel B).

Regarding the 100-km ultramarathon distance, the average sex difference in performance was ~22% for the annual top 10 runners in the "100-km Lauf Biel" over the 1998–2010 period (31). The race times for the top 10 women in the "100-km Lauf Biel" remained stable from 1998 to 2010, whereas race times of the top 10 men became slower across time (31). Similar findings were reported for the "Swiss Alpine Marathon" event, covering a distance of 78 km with a total change in altitude of approximately 2,260 m (11). However, the sex difference in performance was only ~20% for the annual top 10 runners over the years (11). In contrast, in the study of Coast et al. (6) investigating athletes covering distances between 100 m and 200 km, the sex difference accounted to 12.4%.

Ultramarathon running is an outstanding model to analyze the age-related changes in running performance because the energetic loads and demands in an ultramarathon such as 100-km ultramarathon are greater than in a traditional marathon of 42.2 km (26,31). Recent studies investigating "Ironman Hawaii" (18) and 100-miles ultramarathon (45) showed that ultra-endurance performance improved but the change in the age of peak ultra-endurance performance was different. Although the age of peak performance in 100-mile runners remained unchanged across years (45), the age of the best Ironman triathletes in "Ironman Hawaii" increased over time (18).

Therefore, this study expands the existing data relating to age and sex in ultramarathon running by analyzing the age of

Table 3. Multilevel regression analyses for the change in sex differences across years for the annual fastest and the annual 10 fastest runners (model 1) and with correction for multiple finishes (model 2).

	Model	β	*SE* (β)	Stand. β	*T*	*p*
Annual fastest	1	−0.652	0.076	−0.789	−8.526	<0.0001
	2	−0.652	0.076	−0.789	−8.526	<0.0001
Annual 10 fastest	1	−0.526	0.027	−0.714	−19.295	<0.0001
	2	−0.526	0.027	−0.714	−19.295	<0.0001

peak ultra-running performance of all 100-km ultramarathoners competing worldwide from 1960 to 2012. Within this framework, the aims of this study were to examine (a) the change in 100-km running performance for both women and men from 1960 to 2012 and (b) the age of peak ultra-running performance in 100-km ultramarathon during the same period. Regarding existing literature, we hypothesized (a) an improvement of

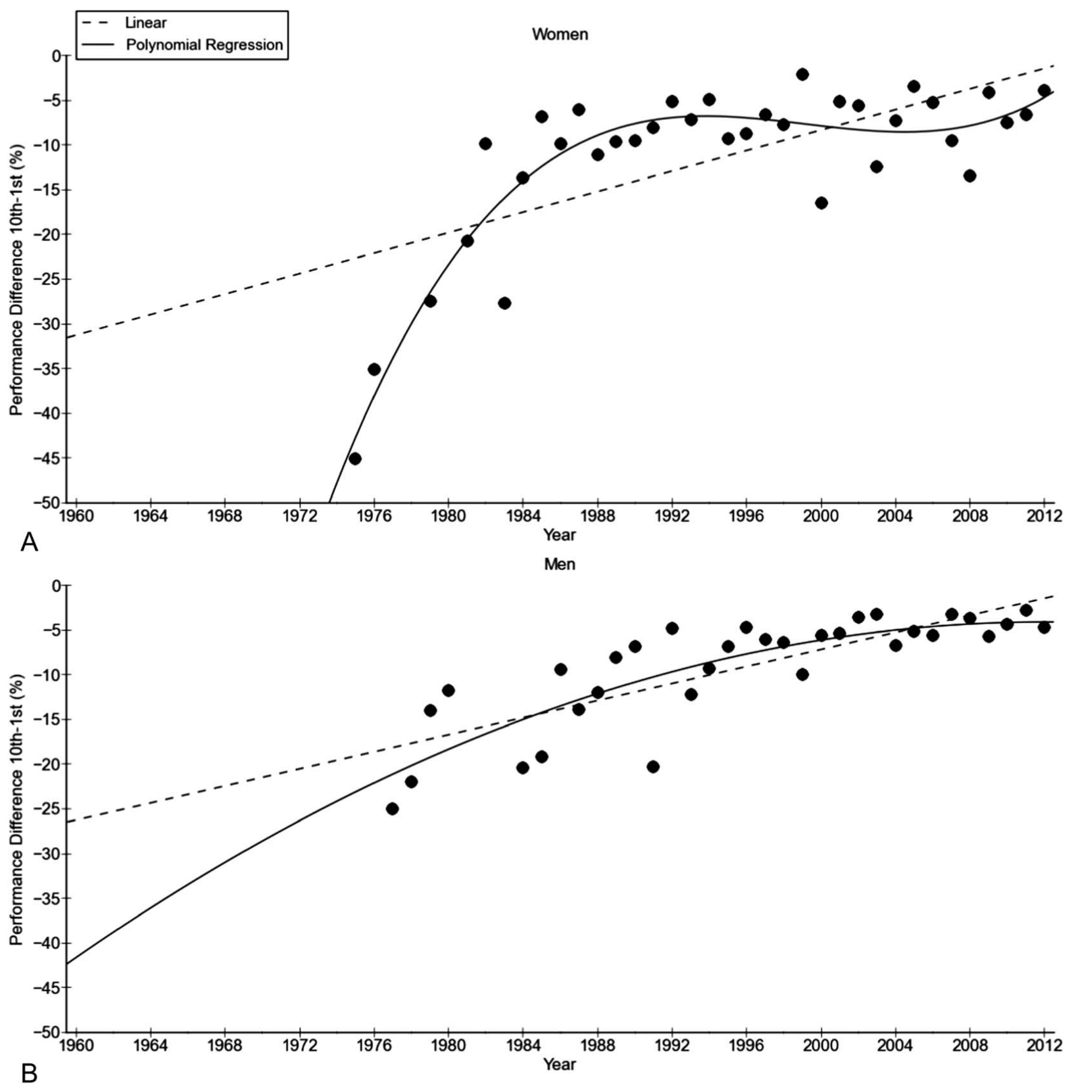

Figure 4. Difference in running speed between the winner and the 10th place expressed as a percentage of the winner time for both women (panel A) and men (panel B).

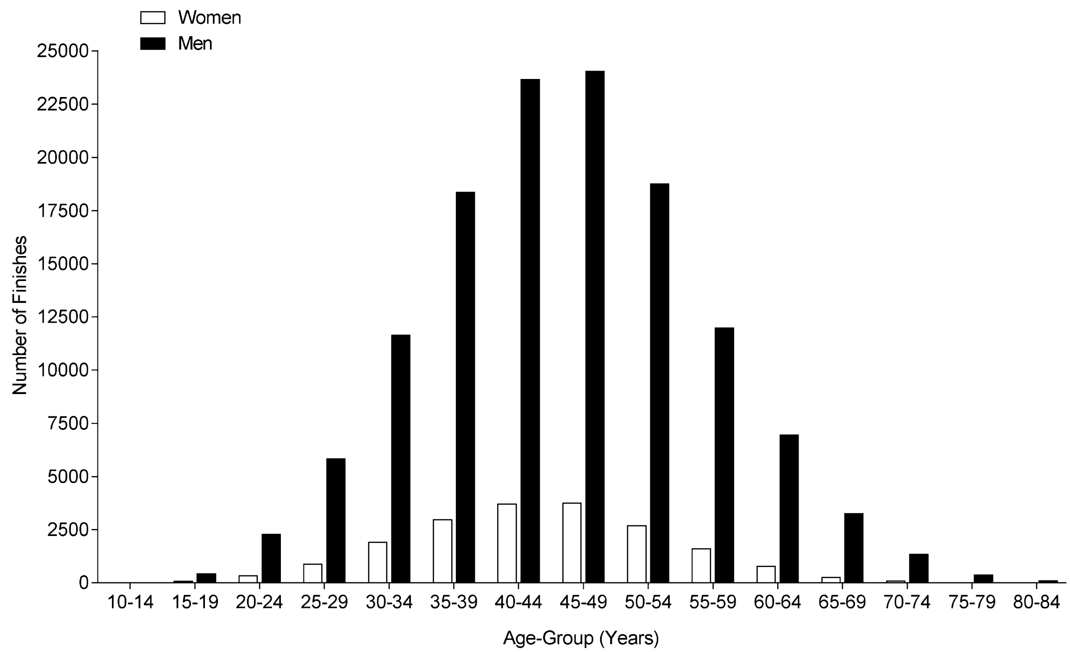

Figure 5. Distribution of the finishes in age groups for women and men.

running performance of 100-km ultramarathoners and (b) that the age of peak ultra-running performance would increase during the studied period. The knowledge of the age of peak ultramarathon performance would help athletes and coaches to plan an ultramarathon career.

METHODS

Experimental Approach to the Problem

To test our hypotheses, all women and men whoever finished worldwide in a 100-km ultramarathon between 1960 and 2012 were analyzed regarding aspects of participation, performance, and age.

Subjects

Subjects between 18 and 84 years were all finishers of all 100-km ultramarathons held worldwide between 1960 and 2012. The data set for this study was obtained from the race Web site www.ultra-marathon.org. This database records every result of any ultramarathon held worldwide. The study was approved by the Institutional Review Board of St. Gallen, Switzerland, with a waiver of the requirement for informed consent given that the study involved the analysis of publicly available data.

Procedures

To determine peak running performance and the age of peak running performance, race times of the annual top and of the annual top 10 women and men were determined and further analyzed. Performance was expressed as running speed ($km \cdot h^{-1}$) using the equation (running speed [$km \cdot h^{-1}$]) = (race distance [km])/(race time [h]). If less than the needed amount of athletes was available in a certain year, the respective year was excluded from data analysis. Additionally, the density in performance between the winner and the 10th place was determined if possible (i.e., at least 10 finishers in the respective year) using the equation (performance density between the first and 10th places) = (performance of the 10th place − performance of the first place)/(performance of the first place) × 100, and thus expressed as percentage of the winners performance.

Statistical Analyses

To increase the reliability of the data analyses, each set of data was tested for normal distribution and for homogeneity of variances before statistical analyses. Normal distribution was tested using a D'Agostino and Pearson omnibus normality test, and homogeneity of variances was tested using a Levene's test. Trends in performance were analyzed using regression analysis with "straight line" and "exponential growth equation" model, whereas for each set of data (e.g., each sex) both models where compared using Akaike's information criteria (AIC) to decide which model shows the highest probability of correctness. Single- and multilevel regression analyses were used to investigate changes in performance and age of the finishers across years. A hierarchical regression model was used to avoid the impact of a cluster effect on results in case one athlete finished more than once in the annual top or annual top 10 for the analysis of the

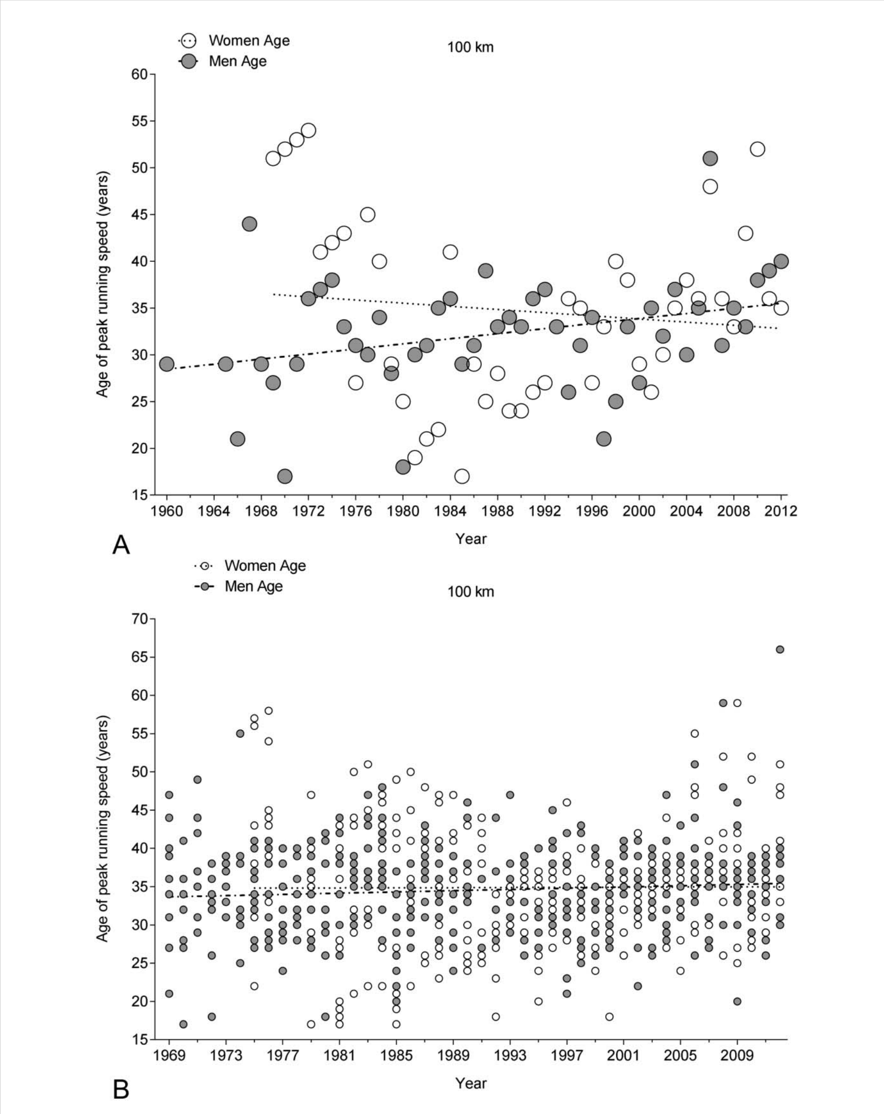

Figure 6. Age of the annual fastest women and men (panel A) and the annual 10 fastest women and men (panel B).

annual top and annual top 10 athletes regarding the analysis of the overall performance and the age of peak performance. Furthermore, regression analyses of performance were corrected for age of athletes to prevent misinterpretation of an "age effect" as a "time effect." Because the change in sex difference in endurance is assumed to be nonlinear (44), we additionally calculated for running speed, sex difference, and performance density using the non-linear regression model to compare with the linear model to find the best model. Because the best-fit model was in all cases a polynomial regression, we compared the best-fit models to the linear models using AIC and *F*-test to show which model would be the most appropriate to explain the trend of the data (Table 1). Statistical analyses were performed using IBM SPSS Statistics (version 21; IBM SPSS, Chicago, IL, USA), CurveExpert Professional (version 2.0.3; Hyams D.G., Huntsville, AL, USA), and GraphPad Prism (version 6.01; GraphPad Software, La Jolla, CA, USA). Significance was accepted at $p \leq 0.05$ (2-sided for *t*-tests). Data in the text and figures are given as mean ± *SD*.

Results

Participation Trends

Complete data with age and race time were available for 148,017 finishers with 18,998 women and 129,019 men. For both women and men, the number of finishes increased exponentially across years (Figure 1). The percentage of female finishes increased from 3.8% in 1969 to 15.0% in 2012 with an average female participation of 12.8 ± 5.3% across all years.

Performance Trends

Running speed of the annual fastest women increased from 8.06 $km \cdot h^{-1}$ in 1969 to 13.22 $km \cdot h^{-1}$ in 2012 (polynomial regression sixth degree, $r^2 = 0.87$, $SE = 0.63$; Figure 2A) and in the annual fastest men from 8.67 $km \cdot h^{-1}$ in 1960 to 15.65 $km \cdot h^{-1}$ in 2012 (polynomial regression fourth degree, $r^2 = 0.79$, $SE = 0.81$; Figure 2B) also when controlled for multiple finishes (Table 2). For the annual 10 fastest women, running speed increased from 7.18 ± 1.54 $km \cdot h^{-1}$ in 1975 to 13.03 ± 0.18 $km \cdot h^{-1}$ in 2012 (polynomial regression second degree, $r^2 = 0.84$, $SE = 0.54$; Figure 2C) and for the annual 10 fastest men from 10.23 ± 1.22 $km \cdot h^{-1}$ in 1969 to 15.05 ± 0.29 $km \cdot h^{-1}$ in 2012 (polynomial regression fourth degree, $r^2 = 0.94$, $SE = 0.28$, Figure 2D) also when controlled for multiple finishes (Table 2). The sex difference in running speed decreased from 56.1% in 1965 to 16.3% in 2012 for the annual fastest finishers (polynomial regression fourth degree, $r^2 = 0.87$, $SE = 4.21$; Figure 3A) and from 46.7 ± 8.7% in 1975 to 14.0 ± 1.2% in 2012 for the annual 10 fastest finishers (polynomial regression fifth degree, $r^2 = 0.86$, $SE = 0.92$; Figure 3B) also when controlled for multiple finishes (Table 3). The density in performance from the 10th to the fastest competitor

Table 4. Multilevel regression analyses for change in age across years for the annual fastest and annual 10 fastest women and men (model 1) and with correction for multiple finishes (model 2).

	Model	β	*SE* (β)	Stand. β	*T*	*p*
Annual fastest men	1	0.136	0.058	0.321	2.321	0.025
	2	0.136	0.058	0.321	2.321	0.025
Annual fastest women	1	−0.085	0.116	−0.112	−0.731	0.469
	2	−0.085	0.116	−0.112	−0.731	0.469
Annual 10 fastest men	1	0.041	0.022	0.088	1.856	0.064
	2	0.041	0.022	0.088	1.856	0.064
Annual 10 fastest women	1	0.005	0.039	0.007	0.124	0.902
	2	0.005	0.039	0.007	0.124	0.902

increased in women from −45.1% (1986) to −3.9% (2012) (polynomial regression third degree, $r^2 = 0.82$, $SE = 4.07$; Figure 4A) and in men from −28.6% (1969) to −5.4% (2012) (polynomial regression second degree, $r^2 = 0.69$, $SE = 3.48$; Figure 4B).

Age Trends

Most of the finishers were classified in the age group 45–49 years for both women and men (Figure 5). The age of the annual fastest men increased from 29 years in 1960 to 40 years in 2012 (Figure 6A) also when controlled for multiple finishes (Table 4). The age of the annual fastest women remained unchanged at 35.0 ± 9.7 years between 1969 and 2012, also when controlled for multiple finishes (Table 4). For the annual 10 fastest women and men, the age of the fastest competitors remained unchanged at 34.9 ± 3.2 and 34.5 ± 2.5 years, respectively (Figure 6B), also when controlled for multiple finishes (Table 4).

Discussion

The aims of this study were to (a) examine the change in 100-km ultra-running performance for both women and men from 1960 to 2012 and (b) determine the age of peak ultra-running performance in 100-km ultramarathon during the same period. The main findings were (a) an exponential increase in number of both female and male finishers with ~13% of female participation, (b) the running speed of the annual fastest women and men improved over time, and (c) the age of the fastest runners remained unchanged across years at ~35 years for both women and men.

The number of both female and male 100-km ultra-runners finishers increased across years. Similarly, Rüst et al. (45) reported an exponential increase in the number of 100-miles ultramarathoners. Apart from ultra-running, also other ultra-endurance disciplines such as ultra-swimming (10,16) enjoyed an increase in participation in the past decades.

In 100-miles races held in the USA, the annual number of races and the annual number of finishes increased exponentially through a combination of an increase in the participation of runners older than 40 years and a growth in the participation of women (23). Also for 100-km ultramarathoners, Knechtle et al. (31) reported that the number of master athletes from the age groups 40–49 years and 50–59 years for both women and men increased from 1998 to 2010 in the "100-km Lauf Biel" in Switzerland. The number of master athletes is expected to increase, as the population in both developed and developing countries are aging caused by the substantial gain in longevity and a decreasing fertility worldwide (41,52).

Women represented on average for ~13% of the total field of ultra-runners with an increase from 3.8% in 1969 to 15.0% in 2012. Similar findings were reported in other studies such as in the 78-km "Swiss Alpine Marathon," where women's participation increased from ~10% in 1998 to 16% in 2011 (11). In 100-miles ultramarathons, the percentage of female finishers increased from 16.7 to 19.1% between 1998 and 2011 (45). Hoffman et al. (21) reported a sex difference in participation of ~20% for 161-km ultramarathoners. The different results might be explained by the different lengths of the races and the different time periods. Additionally, motivation might act as a fundamental reason for the low women participation rate and to the great attendance of men (8,9,19,34). For female ultra-runners, the main drivers for involvement were noncompetitive factors such as general health orientation and psychological coping (34). Women's incentives to exercise are to improve their fitness level and physical health, to gain affiliation and to control their body weight (19). Women ultra-runners seem to be task oriented, motivated by personal achievement and health conscious individuals (34). In contrary, men have a predisposition for long-lasting competitiveness and thus motivated to train with a high volume (8,9).

In accordance with our hypothesis to find an improvement of running performance of 100-km ultramarathoners, performance in both female and male 100-km ultramarathoners improved across years. Similar findings with an improvement in performance have been reported for 100-miles ultramarathoners competing in the "The Western States 100-Mile Endurance Run" (24) and in the worldwide analysis for 100-miles ultramarathons (45). Also in other ultramarathons such as "Badwater," running performance improved in both women and men (7). However, in the "Spartathlon," both women and men were not able to improve race times in recent years (7). Most probably athletes in the longest and toughest ultramarathons held worldwide have now reached their performance limit.

The sex difference in running speed decreased across years for both the annual fastest and the annual 10 fastest finishers. In 2012, the sex difference was 16.3% for the annual fastest and 14.0% for the annual 10 fastest finishers. These values were slightly lower compared with previous studies where the average sex difference accounted to 17–20% for the fastest finishers and 20–22% for the top 10 runners (11,21,31). Interestingly, the sex difference in ultramarathon performance showed no change for 100-miles ultramarathoners competing between 1998 and 2011 (45). The sex difference in performance remained unchanged at 15.0 $\pm$ 8.3% for the annual fastest and at 17.0 $\pm$ 4.1% for the annual 10 fastest finishers (45). Most probably, the longer distance in 100 miles (161 km) compared with 100 km might explain this difference.

In the study of Coast et al. (6) relating to running distances between 100 m and 200 km, the sex difference accounted to 12.4%. The existing sex gaps in running performance can partly be attributed to physiological sex differences such as the lower skeletal muscle mass and the lower cardiac output in women compared with men (5,39). Hunter et al. (25) showed that the physiological sex difference in marathon running velocity was not the only cause of the sex difference. The non-physiological difference could be attributed to the lower number of women finishers relative to men because of a sampling bias (25). Therefore, the lower participation rates of women compared with men can have a large influence on the sex difference in running, and the sampling bias may mask the physiological limits of women (25). Lombardo (38) argued that sport began as a method for men to evolve the abilities needed in primitive hunting and warfare. Hence, sports reveal the skills required for success at fighting and primitive hunting, which could be an advantage for men finishers (38). Other explanations for men's dominance in distance running could be the greater training motivations in men (8,9). To succeed in distance running, enduring competitiveness is an important factor (8,9). Deaner (8) hypothesized that men were substantially more competitive than women and therefore more motivated to engage in high-volume training.

The average time difference between the winner and the 10th placed athlete decreased in both men and women. In 2012, this time difference was smaller for women than for men. The density for the top 10 finishers was higher for women than for men. The density for the top 10 men and the top 10 women was approximately the same in 2012.

It has been postulated that women may outperform men with increasing race distance (1,6). It has been previously observed that female ultramarathoners were more resistant to fatigue than comparable male ultramarathoners (1). The present findings display that the sex gap in 100-km ultramarathon running became reduced since 1960. However, Sparling et al. (50) reported that the sex difference in distance running performance has not changed between 1980 and 1996. Although the sex difference decreased across years, it seems unlikely that women will be faster than men in the near future in 100-km ultramarathon distance.

We hypothesized that the age of peak ultra-running performance would increase during the studied period. However, the annual top 10 women and men were of the same age of ~35 years between 1969 and 2013. Although other studies showed that the age of peak ultra-endurance performance increased across years (18,24), analyses of Olympic track and field and swimming data between 1896 and 1980 showed that the age at which peak performance was achieved remained remarkably consistent (48).

The age of peak ultramarathon performance might increase with increasing length or duration of a race. In 100-miles ultramarathoners, the age of the annual fastest women was 39.0 $\pm$ 5.5 years for women and 37.0 $\pm$ 6.0 years for men with no change across years (45). Similarly, the age of the annual 10 fastest finishers was 39.2 $\pm$ 6.2 years for women and 37.2 $\pm$ 6.1 years for men with no change across years (45). In 24-hour ultramarathoners, the best runners were even older than 40 years (53). The age of the annual top 10 women decreased from 42.6 $\pm$ 5.9 years to 40.1 $\pm$ 7.0 years. For the annual top 10 men, the age of peak running speed remained unchanged at 42 $\pm$ 2 years. Future studies need to investigate the age of peak performance in longer races such as continental crossing like "Run across America" or "Trans Europe Foot Race."

The present findings confirm the results of Tanaka (52) regarding running distances up to 42 km, that peak endurance performance in running is sustained until ~35 years of age. An accumulation of training years and of experience in such ultra-endurance races is essential for a success finish in endurance running until the velocity is outbalanced by human aging (14,24,29,31). The aging process in humans is described by a functional degeneration in the major biological system (42) including the cardiovascular (4), metabolic (40), respiratory (48), and musculoskeletal (15) systems. Also, the atrophy of skeletal muscles is not perceivable for most people until the age of 40 years (15). Accordingly to Faulkner et al. (15), a significant atrophy of the skeletal muscles occurs mainly beyond the age of 50 years. According to Tanaka (52), the physiological determinants such as maximum oxygen consumption ($\dot{V}O_2max$) and lactate threshold are mainly responsible for decline in performance with increasing age. Regarding combinations of physiological factors (52), skeletal muscle (15), and number of training years (29), 100-km ultramarathoners seemed to achieve their best performances in their mid-30s.

The age classification system differs from sport to sport in accordance to the age at which the world record peaks (43). Master athletes are defined as runners over the age of 35 years who are keen and competitive athletes (43). According to the current age-based category in running, the world best 100-km ultramarathon runners are close to master athletes, by definition.

The strength of this study is the large sample size and the inclusion of multivariate and nonlinear regression analyses. However, although the database seems highly reliable, some smaller races might not be included leading to a selection bias. Regarding the study design, a limitation in this cross-sectional study is the fact that we were unable to take into consideration factors of endurance performance such as physiological (35,40,46) and anthropometric parameters (28,29), training (29,32), previous experience (28,30), fluid and food intake (2,3), motivation (20,34), medical problems (33,47), and environmental conditions of the race (12,13). Nevertheless, this study reveals beneficial information, because it expands the existing data of age and gender influence in ultramarathon running.

Practical Applications

The number of female and male finishers increased exponentially in 100-km ultramarathon races held worldwide between 1960 and 2012. Running speed increased for the annual fastest and annual 10 fastest women and men. The sex difference decreased to 16.3% for the annual fastest and to 14.0 ± 1.2% for the annual 10 fastest finishers. The age of the annual 10 fastest finishers was at ~35 years for both women and men. To conclude, 100-km ultramarathoners became faster, the sex difference in performance decreased, but the age of the fastest finishers remained unchanged at ~35 years. For athletes and coaches, 100-km ultramarathoners improved performance between 1960 and 2012; however, the age of the fastest athletes remained unchanged at 35 years over time. To plan a career as a 100-km ultramarathoner, the fastest 100-km race times will be achieved at the age of ~35 years for both women and men.

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